Desalination Demonstration Report for Buena Vista Water Storage District

Buena Vista Water Storage District

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Disclaimer: This report summarizes the results of studies, which investigate the performance and fouling behavior of low-pressure reverse osmosis and nanofiltration membranes for treating subsurface agricultural drainage water for the California Department of Water Resources. Publication of any finding or recommendations in this report should not be construed as representing the concurrence of the Department. Also, mention of trade names or commercial products does not constitute Department endorsement or recommendation.

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Executive Summary

The area served by the Buena Vista Water Storage District (BVWSD), as well as other areas within the San Joaquin Valley, consists primarily of irrigated farmland. In order to prevent the dissolved salts in the irrigation water from concentrating in the root zone, it is necessary to apply irrigation water in excess of the crops' consumptive use to carry the salts below the crops' root zones. A semi-permeable clay layer about 100 feet to 200 feet below ground surface limits the depth to which the water can percolate resulting in a shallow, saline groundwater aquifer.

During the irrigation season, the water level rises to within a few feet of the ground surface. Evaporation of some of the water, adjacent saline subsurface flow, and long-term historical irrigation patterns have caused the shallow saline groundwater to increase the soil salinity in the crop root zones resulting in lower crop yields. This has forced some and is threatening to force more land out of agricultural production.

On-farm tile drainage systems are used in some areas of the San Joaquin Valley to keep the saline shallow groundwater below the crop root zone. Disposal of the collected drainage water is a major problem that must be addressed.

The drainage water, however, can also be considered as a potential water source. Desalting of the drainage water is necessary to make the water usable. A reverse osmosis (RO) desalination demonstration plant was implemented to demonstrate the feasibility of desalting the drainage water and converting what is now a liability into an asset.

The objectives and results of the RO desalination demonstration plant are summarized below:

OBJECTIVE	RESULT
1. Demonstrate the ability of commercially available reverse osmosis (RO) membranes to treat agricultural drainage water	Removed approximately 97% of dissolved solids and obtained a 75% water recovery.

OBJECTIVE	RESULT
2. Evaluate pretreatment methods to determine their effectiveness in providing suitable supply (feed water) for the RO system.	Both direct multi-media and sand filters as well as alum (coagulant) were used to pre-treat the feed water. Both filters successfully produced the desired RO feed water quality.
3. Evaluate the quality of water that can be expected from a typical tile drain system.	The water from the tile drain system proved to be high in total dissolved solids (TDS) concentration as expected, but also contained algae and suspended solids.
4. Demonstrate the level of effort necessary for operating a RO system designed to treat agricultural drainage water.	It was demonstrated that one operator could operate the system.
5. Provide data to support permitting of the construction and operation of a full-scale RO system treating agricultural drainage water.	Water quality data gained from the RO demonstration process will help to support the necessary permitting.
6. Provide data supporting potential marketing efforts for new water supplies produced by treating agricultural drainage water.	Water quality data gained from the RO demonstration process will help to support the potential for marketing.
7. Provide data supporting development of cost opinions for full-scale treatment.	Cost estimates to support full-scale implementation for irrigation supply are presented in **Tables 6** and **7**.
8. Determine the appropriate pretreatment filtration system necessary to facilitate maximum RO performance and RO membrane operation lifetime.	Data showed that either multimedia or sand filters would perform adequately with standard chemical coagulant.
9. Determine the effectiveness of shallow wells for reclaiming land impacted by drainage.	The shallow wells lowered the shallow saline water table elevation and provided a more reliable raw water supply for the demonstration project

This RO demonstration project, conducted during the growing seasons of 2000 and 2002, evaluated the possibility of desalting the shallow

saline groundwater recovered by a tile drain system and two shallow wells to produce an irrigation water supply. The drainage water was treated using RO resulting in as much as 97% removal of the dissolved solids from the feed water. About 75% of the RO feedwater was recovered as potentially usable water. The remaining water, containing the dissolved solids removed from the raw water, required disposal.

The average total dissolved solids concentration in the desalted water and the shallow groundwater were 230 mg/L and 4,000 mg/L, respectively.

Based on the water quality analyses obtained from both the 2000 and 2002 irrigation seasons, the desalted water can be used for irrigation. Data obtained demonstrated that desalted water of this quality could be produced on a consistent basis using RO to provide a usable water supply.

Table ES-1 summarizes the range of capital and O&M costs for full-scale treatment at varying productions rates.

Table ES-1. Cost Estimates for Full Scale Treatment

Production (MGD)	1	2	5	10
Capital Cost (M$)	$2.9	$5.0	$10.6	$21.3
O&M Cost (M$)	$0.4	$0.6	$1.6	$3.1
Water Cost ($/AFY Produced)	$618	$490	$452	$443

Figure ES-2. Buena Vista RO Desalination Demonstration Pilot Trailer

Introduction

Saline agricultural drainage water within the Buena Vista Water Storage District is accumulating in shallow aquifers located below productive farmland. This saline water has risen to elevations where it increases the soil salinity in crop root zones resulting in reduced crop productivity and in some areas of the District, lands have been taken out of production because of the high saline groundwater table.

A reverse osmosis pilot plant was constructed to demonstrate the feasibility of desalting saline irrigation drainage water for use as a water supply for agricultural or municipal use. The demonstration plant was constructed in the Buena Vista Water Storage District northwest of Bakersfield, California. The plant operated during the irrigation seasons of 2000 and 2002.

Initially, the saline groundwater used as feedwater for the RO demonstration plant was collected by a tile drain system that was installed in November 1999. The water flowed into a sump. It was then pumped to the plant.

In 2001, however, the tile drain system did not produce enough water to operate the RO demonstration plant. Therefore, two shallow wells were drilled in December of 2001 to provide a more reliable feedwater source to the RO demonstration unit.

Definition of Terms

- Permeate: desalted water exiting RO process
- Concentrate: wastewater exiting RO process
- Filtrate: water exiting pretreatment filters
- Feed: source water entering pretreatment filters (saline drainage water)
- Recovery: percentage of feed water recovered as permeate

Participants

A number of organizations participated in the preparation and operation of the demonstration plant.

The Buena Vista Water Storage District served as the contractor and the project administrator for the California Department of Water Resources (DWR), the main project sponsor. Dave Bloemhof of Bloemhof Farms provided the RO demonstration site. Supplemental funding was provided by:

- Kern County Water Agency
- Lost Hills Water Storage District
- Semitropic Water Storage District
- Wheeler Ridge – Maricopa Water Storage District

Boyle Engineering Corporation provided engineering services, the RO demonstration plant, and plant operators. The sampling and analysis plan, engineering services, laboratory services, and pretreatment filters were provided by DWR. Technical support was provided by UCLA and field support was provided by BVWSD staff as needed from time to time.

Study Objectives

The study was intended to meet several objectives:

1. Demonstrate the ability of commercially available RO membranes to treat agricultural drainage water.
2. Evaluate pretreatment methods to determine their effectiveness in providing suitable feed water for the RO system.
3. Evaluate the quality of water that can be expected from a tile drain system.
4. Demonstrate the level of effort necessary for operating a RO system designed to treat agricultural drainage water.
5. Provide data to support permitting of the construction and operation of a full-scale RO system treating agricultural drainage water.

6. Provide data supporting potential marketing efforts for new water supplies created by desalting agricultural drainage water.
7. Provide data supporting development of cost opinions for full-scale treatment.
8. Determine an appropriate pretreatment filtration system necessary to facilitate maximum RO performance and RO membrane operation lifetime.
9. Demonstrate the effectiveness of shallow wells as a feedwater to an RO plant and determine impact on ground water levels.

Testing Protocol

The following demonstration test protocol was developed to provide evidence that the objectives listed above were attained.

- **Particle removal verification**: The feed water Silt Density Index (SDI) should be below 3.0. The performance of both pretreatment filtration systems indicated that this requirement could be met on a consistent basis.
- **Fouling constituent verification**: Analyses of the feed and filtrate stream samples were taken to show that potential RO membrane fouling constituent concentrations were at levels which do not negatively impact membrane life and performance. Based on the analytical data, RO membrane fouling will occur at acceptable rates as long as the proper amounts of scale inhibitor and acid are injected into the RO feed stream.
- **Product water quality verification**: Analyses of the permeate indicated that RO is capable of producing water that can be utilized for potable or agricultural use.

Analytical Sampling and Systems

Table 1 is an outline of the analyses that were performed on a daily, weekly and monthly basis. The onsite operator performed daily analyses and DWR's Bryte Laboratory performed the weekly and monthly analyses.

Table 1. Analytical Schedule

Analysis	Sample Location											
	Feed			Filtrate (2 units)			Permeate			Concentrate		
	Daily	Weekly	Monthly	Daily	Weekly	Monthly	Daily	Weekly	Monthly	Daily	Weekly	Monthly
Turbidity	X	X	X	X	X	X		X	X		X	X
EC	X	X	X		X	X	X	X	X	X	X	X
Temp.				X			X					
TDS		X	X		X	X		X	X		X	X
Calcium		X	X		X	X		X	X			X
Magnesium		X	X		X	X		X	X			X
Sodium		X	X		X	X		X	X			X
Carbonate*		X	X		X	X		X	X			X
Bicarb.*		X	X		X	X		X	X			X
Chloride			X			X			X			X
Sulfate			X			X			X			X
Boron			X			X			X			X
SiO2			X			X			X			X
Barium			X			X			X			X
Strontium			X			X			X			X
Selenium			X						X			X
TSS			X			X						
TOC			X			X			X			X
UV254			X			X			X			X
SDI				X								
Other analyses as needed: pH, fluoride, iron, nitrate, nitrite, orthophosphate, potassium and DOC												

Schedule of Operation

Initially, the desalination demonstration project was to operate throughout the 2000 and 2001 irrigation seasons. However, due to the lack of water from the tile drain system, the project was not able to maintain sustained operation in 2001. The project was extended for a year, and modified by the inclusion of two shallow wells to provide a more reliable drainage water supply. These wells were completed in December 2001, and RO demonstration continued through the 2002 irrigation season.

The data in this report reflects the RO demonstration plant's operation from June 27 to September 13, 2000 and from April 1 to December 4, 2002. The data focuses mainly on the year 2002 irrigation season when sustained RO operations were maintained.

Operation during the previous years is described in the following reports:

- Pilot Design Report for Buena Vista Water Storage District, June 2000
- Desalination Pilot Report for Buena Vista Water Storage District, December 2000
- Phase 2 Demonstration Project Report for Buena Vista Water Storage District, January 2002